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THE USE OF A REFRACTOMETER WITH VARIABLE REFRACTING ANGLE

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The precise determination of refractive indices above $n=1.8$ constitutes a problem that is frequently vexing to the petrographer. The difficulty is due primarily to two causes: (1) the actual determination of the index of refraction, and (2) the lack of suitable immersion media that will not dissolve or react chemically with the substance under investigation.

In the actual determination of indices of refraction, and particularly the higher indices, the refractometer with variable refracting angle has proved to be a valuable instrument. The examination of liquids with indices beyond the range of the Abbé refractometer, constitutes a use for which the instrument is especially well fitted. Its range of application is unlimited and extends from $n=1$ to $n=\infty$.

LITERATURE

The literature describing the operation of the refractometer with variable refracting angle is lacking in many important details. When examining solids, the principle involved is similar to that of the prism method of F. Kohlrausch,[1] but the design of the apparatus is so different that the similarity of principle is not readily evident. In the limiting case the method becomes that of grazing incidence and normal emergence, and it is possible to take advantage of this simplified procedure in determining the index of refraction of fluids. The method of application of the refractometer with variable refracting angle, as used in the examination of fluids, has been described in the literature of Carl Zeiss, Jena.[2] The essence of this description is included here for the sake of completeness.

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[1] F. Kohlrausch, *Wiedemann's Ann.*, XVI, 603, 1882.

[2] Optische Ausrüstungen für mineralogische Untersuchungen, *Mess 449*, 26–28. This publication has been translated into English.

The application of the refractometer to solids involves a much more complicated procedure, and the existing literature on this subject is entirely inadequate.

EXAMINATION OF FLUIDS

The fluid is enclosed between two plane-parallel glass plates and the refracting angle of the prism thus produced may be varied as desired. One of the glass plates (*G* in Figure 1) serves as the horizontal floor for the cell which contains the fluid *F*. The other glass plate *T* is permanently attached to a telescope, below the objective lens, in such a manner that the plane-parallel ends are exactly normal to its optical axis. Actually this "plate" has the form of a slightly tapering cylinder, the lower end of which dips into the fluid.

Monochromatic light entering the plate *G* by grazing incidence, because of its plane-parallel sides is transmitted to the fluid *F* in a manner equivalent to grazing incidence. The ray consequently follows the critical angle *r* of total reflection in its course through the fluid *F*. When the optical axis of the telescope, or the normal to the plate *T*, is so oriented that it coincides with the direction of the limiting ray passing through the fluid, the critical angle *r* of total reflection is equal to the angular rotation of the telescope from the vertical position. The index of refraction of the fluid *F* is therefore

$$n=\frac{1}{\sin r}.$$

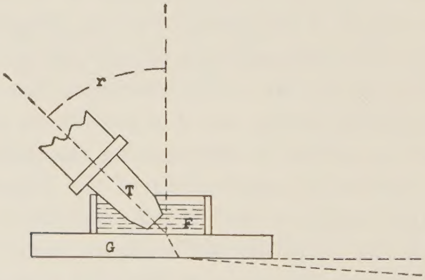

FIG. 1

Since the method of grazing incidence is always employed in the operation of this refractometer, it is not necessary to know the refractive indices of plates *G* and *T*. In the construction of these plates it is possible to use glass that is highly resistant to chemical corrosion.

Control of the temperature of the fluid, as in the double variation method, may be obtained by substituting a hollow glass cell for the plate G and allowing water to flow through it. Care must be taken that the walls of the cell are constructed from plane-parallel glass plates and that the assembled cell also has parallel upper and lower surfaces. It is also possible to apply the monochromatic light by grazing incidence at the upper surface of the cell or plate G, provided that one end of the plate or cell has been polished in order to allow the passage of the incident rays.

The refractometer is not well adapted to the determination of indices of highly volatile liquids because it is not feasible to cover them.

Examination of Solids

The determination of the index of refraction of a solid body involves a more complicated procedure, but the principle is similar to that of the prism method devised by F. Kohlrausch.[3]

It is necessary to construct a prism from the substance whose index of refraction is to be determined, and to accurately measure the angle θ of this prism. The prism is then placed upon a plane-parallel glass plate G, using a drop of water or oil between them. (See Figures 2 and 3.) The critical line of total reflection is observed through the viewing telescope as in the case when examining fluids, and the angle R is obtained from the scale on the refractometer.

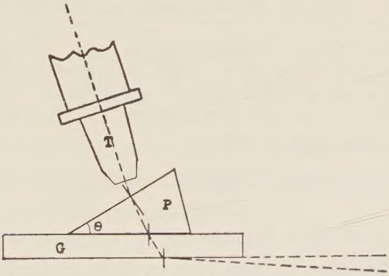

Fig. 2

In the limiting case where R happens to equal the prism angle θ, we have the condition of grazing incidence and normal emergence and consequently $n = \frac{1}{\sin R}$. In all other cases the method of calculating the index of refraction may be derived as follows:—

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[3] F. Kohlrausch, *Wiedemann's Ann.*, XVI, 603, 1882.

In the general case in which a ray S (Figure 3) passes from a medium whose index of refraction is N, and enters a prism whose index of refraction is denoted by n, we have the following relations:

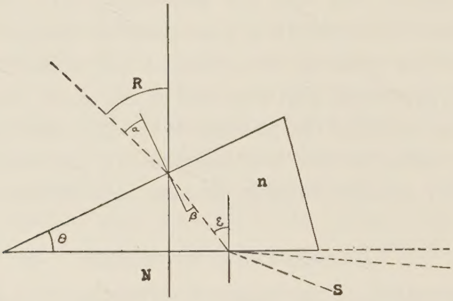

FIG. 3

$$n = \frac{\sin\alpha}{\sin\beta} = \frac{N}{\sin(\theta \pm \beta)}$$

when $R > \theta$, then $\epsilon = \theta + \beta$ and

$$N \sin\beta = \sin\alpha \sin(\theta + \beta)$$
$$N \sin\beta = \sin\alpha \sin\theta \cos\beta + \sin\alpha \cos\theta \sin\beta$$
$$\frac{N \sin\alpha}{n} = \sin\alpha \sin\theta\sqrt{1 - \frac{\sin^2\alpha}{n^2}} + \frac{\sin\alpha \cos\theta \sin\alpha}{n}$$
$$\frac{N \sin\alpha}{n} = \frac{\sin\alpha \sin\theta\sqrt{n^2 - \sin^2\alpha}}{n} + \frac{\sin\alpha \cos\theta \sin\alpha}{n}$$
$$N \sin\alpha = \sin\alpha \sin\theta\sqrt{n^2 - \sin^2\alpha} + \sin\alpha \cos\theta \sin\alpha$$
$$N = \sin\theta\sqrt{n^2 - \sin^2\alpha} + \sin\alpha \cos\theta \qquad (1)$$

Similarly when $R < \theta$, then $\epsilon = \theta - \beta$ and

$$N = \sin\theta\sqrt{n^2 - \sin^2\alpha} - \sin\alpha \cos\theta. \qquad (2)$$

Since the source of light for the refractometer always enters the prism by grazing incidence, the sine of this angle is equal to unity.

Therefore, when $R > \theta$

$$1 = \sin\theta\sqrt{n^2 - \sin^2\alpha} + \sin\alpha \cos\theta$$
$$1 - \sin\alpha \cos\theta = \sin\theta\sqrt{n^2 - \sin^2\alpha}$$
$$(1 - \sin\alpha \cos\theta)^2 = \sin^2\theta(n^2 - \sin{}^2\alpha)$$
$$1 - 2\sin\alpha \cos\theta + \sin^2\alpha \cos^2\theta = n^2 \sin^2\theta - \sin^2\alpha \sin^2\theta$$
$$n^2 = \frac{1 - 2\sin\alpha \cos\theta + \sin^2\alpha \cos^2\theta + \sin^2\alpha \sin^2\theta}{\sin^2\theta}$$

$$n^2 = \frac{1 - 2\sin\alpha\cos\theta + \sin^2\alpha(\cos^2\theta + \sin^2\theta)}{\sin^2\theta}$$

$$n = \frac{\sqrt{1 - 2\sin\alpha\cos\theta + \sin^2\alpha}}{\sin\theta} \tag{3}$$

Similarly when $R<\theta$

$$n = \frac{\sqrt{1 + 2\sin\alpha\cos\theta + \sin^2\alpha}}{\sin\theta}. \tag{4}$$

Occasionally the writer measures the angle θ of the prism by mounting it on the horizontal revolving stage of the petrographic microscope. A pin-point of light from an arc light source is allowed to fall upon one of the refracting surfaces of the prism and its reflection on the distant wall of the darkened room is marked. The stage is then rotated until the reflection from the other prism surface coincides with the mark, and the prism angle is determined from this angular rotation as in crystal goniometry.

It is usually more accurate, however, to measure the prism angle θ directly on the refractometer, and when any imperfections exist in the prism it is particularly desirable to determine both R and θ without disturbing the position of the prism.

The angle α is equal to R minus θ, or θ minus R, depending on which of these has the greatest magnitude. The index of refraction of any solid prism can therefore be computed by means of equations (3) and (4).

ACCURACY

The accuracy of the refractometer with variable refracting angle necessarily decreases as the index of refraction increases. In the following table n represents the index of refraction, r the critical angle, and dn the error in the value of the index of refraction in terms of the fourth decimal figure corresponding to one minute of error in the determination of r.

n	1.3	1.5	1.7	1.9	2.1
r	50° 17′	41° 49′	36° 2′	31° 45′	28° 26′
dn	3.1	4.8	6.8	9.0	11.5
n	2.3	2.5	2.7	2.9	3.1
r	25° 46′	23° 35′	21° 44′	20° 10′	18° 49′
dn	14.3	16.9	19.7	23.1	26.4

In the examination of solid substances the accuracy of the determination of R is at a maximum when the values of θ and R are equal or nearly equal.

THE ZEISS REFRACTOMETER WITH VARIABLE REFRACTING ANGLE

The Zeiss refractometer with variable refracting angle is shown in Figure 4.* Attached immovably to the base of the instrument and supported on a pillar is a vertical graduated sector divided into half degrees from 0° to 75°. On one side of this rigid sector a radial arm rotates on a horizontal axis. The position of this radial arm, upon which is mounted a vernier giving readings accurately to 1′, is controlled by a gnarled knob which operates a rack and pinion. An adjustable magnifier for reading the vernier is attached

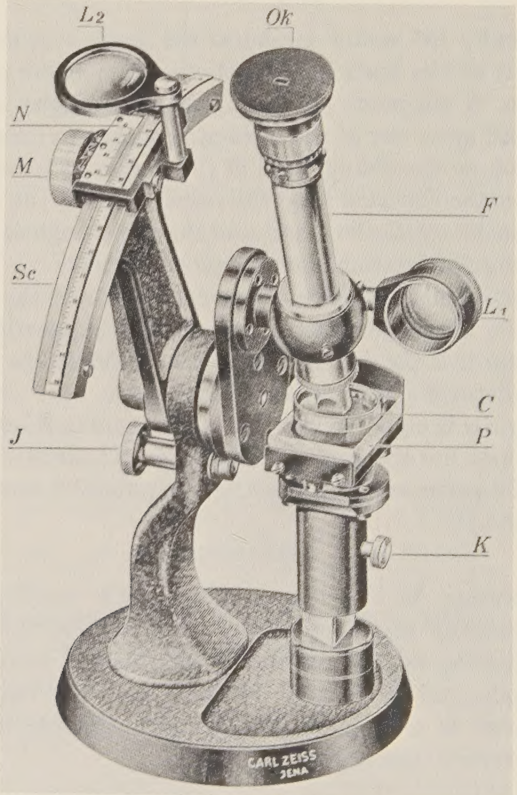

FIG. 4

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* The Zeiss refractometer with variable refracting angle described in Mess **449** is no longer manufactured. The new refractometer shown in Figure 4 has recently been placed on the market. The two refractometers, though necessarily similar in principle, are quite different in detail.

to the end of the radial arm. On the other side of the vertical sector and attached to the radial arm by a horizontal shaft is the viewing telescope. Consequently, as the rack and pinion moves the radial arm along the graduated vertical sector, the optical axis of the telescope may be varied from vertical at 0° to an inclination of 75° from the vertical position.

At the lower end of the viewing telescope is mounted a slightly tapering cylinder of frosted glass 28 mm. in length, whose polished plane-parallel ends are at right angles to the optical axis of the telescope. The lower end of the cylinder is beveled in such a manner that the flat polished surface is bounded by parallel straight edges about 6 mm. apart. The cylinder is so adjusted that one of these edges coincides with the axis of rotation of the telescope.

A second pillar attached rigidly to the base of the refractometer, supports the plane-parallel glass plate upon which the prism or fluid-containing cell is mounted. The plane-parallel glass plate rests loosely upon three capstan screws and is bounded on three sides by a fence. The elevation of the upper part of the plate carrier may be adjusted as desired by means of a clamping screw. It may also be rotated on a vertical axis through small angles in order to set the refracting edge of the prism exactly parallel to the axis of rotation of the telescope. The desired position is found by observation of the reversal of the critical line as the plate carrier and prism are rotated to the right or left.

A collimating lens attached to an easily removable and adjustable support, receives the light from a sodium burner, or other monochromatic source, and transmits it to a slit or window at the front end of the plate carrier. The rays which enter the bottom of the plane-parallel glass plate by grazing incidence must necessarily follow the critical angle of the glass in their course through the plate, and leave the upper parallel surface by grazing emergence if the surrounding medium is air. When a liquid occurs in contact with the upper surface of the plate, the direction of these limiting rays is that of the critical angle of the liquid. If the end of the glass cylinder attached to the viewing telescope is immersed in the liquid, it is possible to incline the axis of the telescope until it coincides with the direction of the critical ray. The critical line of total reflection is placed in contact with the junction of the two cross-lines of the telescope and the critical angle of the liquid is read directly on the scale on the graduated sector.

When the index of refraction of a solid prism is to be determined, the latter is mounted on a plane-parallel glass plate, using a drop of water or other liquid between them. The direction of the critical ray as it emerges into air on leaving the prism is determined by setting the critical line in contact with the junction of the cross-lines of the telescope as before.

Before using the refractometer, care must be taken that the plane-parallel ends of the tapering cylinder are normal to the optical axis of the telescope. The lower straight edge of the polished end of the cylinder should coincide with the axis of rotation of the telescope. When the position of the telescope is set at zero on the graduated sector, the surface of the plane-parallel glass plate must be oriented at right angles to the optical axis of the telescope.

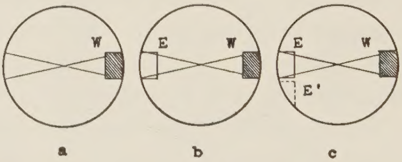

FIG. 5

In order to secure these adjustments, use is made of a small prism or window mounted in the side of the telescope and furnished to illuminate the cross-lines. This projects into the field of the telescope as *W*. (Figure 5*a*). During these adjustments the refractometer is illuminated solely at this small window. If the ends of the glass cylinder are not exactly normal to the telescope axis, an unsymmetrical image of the window will be found at the diametrically opposite side of the field of view. This may be corrected by means of two small capstan screws which produce lateral displacement of the telescope objective. The correct adjustment is secured when the image *E* occupies a position symmetrical to that of the window *W* as in Figure 5*b*.

When the scale of the instrument is set at the zero position, the image *E'* of the illuminated window is reflected from the surface of the plane-parallel glass plate. (Figure 5*c*.). By means of one or more of the three capstan screws which support the plate, the image *E'* is made to coincide with the image *E*.

If these operations have been carried out with sufficient care the refractometer is now in adjustment and ready for the determination of refractive indices. In the normal position (with the scale reading zero) and with the plane-parallel glass plate resting on its carrier, the field of view in the telescope is similar to Figure 5*b* with images *E* and *E′* coinciding with each other. The accuracy of these adjustments must be checked by examining a liquid whose index of refraction is known. Distilled water is the most satisfactory liquid for the standardization of the refractometer.

The upper end of the telescope above the eyepiece is permanently mounted with a cap furnished with a stop to eliminate the light rays derived from sources other than the polished end surface of the tapering glass cylinder. By rotating this cap it is possible to bring the cross-lines of the telescope into sharp focus.

CEMENTS

When examining liquids it is necessary to cement a ring to the upper surface of a plane-parallel glass plate, thus forming a cell or container.

Perhaps the most satisfactory, and at least the most durable cement used by the writer is dental plaster of Paris reinforced by litharge and glycerine. The ring is frosted on its outer surface by rubbing it with fine emery cloth. A circular band is similarly frosted on the upper surface of the glass plate. This is accomplished by temporarily cementing the glass ring to the plate with Canada balsam, and rubbing with the outer surface of the ring and the adjoining surface of the plate with fine emery cloth. The ring is then removed by heating the plate and the balsam is washed off with xylene. After thoroughly cleansing the ring and plate, they are cemented together again with the very minimum of dental plaster of Paris. When dry, the excess plaster is removed from the outer margin as well as the inside of the cell by means of a moistened cotton swab. Litharge and glycerine cement is then added to the outer margin of the ring in contact with the frosted surfaces. The particles composing the plaster of Paris, as well as the litharge, should be of semi-colloidal dimensions. When these operations have been carried out properly, the only cement in contact with the liquid in the cell is an exceedingly thin film of plaster of Paris. Bonding strength is furnished by the litharge and glycerine cement and this is not affected by changes in temperature.

A more simple method of cementation involves the use of dental plaster of Paris reinforced with Canada balsam. The minimum of Canada balsam (cooked until brittle when cold) is used to cement the ring to the plate. Xylene is then placed in the cell to dissolve any excess balsam and partially etch the film between the ring and the plate. Thin plaster of Paris is allowed to flow around the inner margin of the ring, and after removing the excess, a very thin film of plaster remains to coat the inner margin of the balsam. At ordinary temperatures this method of cementation is usually quite satisfactory but its length of service is greatly reduced at higher temperatures.

Regardless of the nature of the materials used to cement the ring to the plate the two most important secrets in the success of the operation are the following:

(1) The surface of the ring must fit the plate with a high degree of accuracy.

(2) In all cases, the very minimum of cement should be used to form the film between the two surfaces.

A properly mounted ring cemented with brittle Canada balsam alone, will retain such solvents as xylene in the cell for a remarkable length of time. A poorly mounted ring may not be able to retain xylene for more than a few minutes.

It is desirable to use cells reinforced with litharge and glycerine as containers for methylene iodide and for alpha-bromnaphthalene. The writer uses one cell exclusively for liquids containing methylene iodide.

COLORED LIQUIDS

When the index of refraction of a liquid is being determined on the refractometer, it is possible to elevate the floor of the cell until it comes in contact with the lower straight edge of the tapering glass cylinder attached to the telescope. Regardless of the depth of liquid in the cell, the thickness of the prism enclosed beneath the end of the glass cylinder is approximately zero at one edge. When the critical line is placed in contact with the junction of the two cross-lines of the telescope, the angle of the prism of liquid enclosed beneath the glass cylinder is equal to the critical angle of the liquid. The higher the index of refraction, the smaller this prism angle will be.

Thus it is seen that even with the weak intensity of the monochromatic light supplied by a sodium burner, the index of refraction of a highly colored liquid may be determined readily.

When reasonably pure, the indices of refraction of all of the liquids commonly used as immersion media, as well as the heavy liquids, can be determined accurately with the refractometer with variable refracting angle.

When used for gravity separations, methylene iodide may become so highly colored that the determination of its index is difficult. This is not due so much to the inability to observe the critical line as to the problem of adjusting it to coincide with the junction of the cross-lines of the telescope. Recently this problem has been largely overcome by placing a small shaded light near the window or prism used to illuminate the cross-lines. An oblique angle will be found at which the incident light from the small lamp illuminates the cross-lines without masking the critical line.

CONSTRUCTION OF THE PRISM

For the determination of the refractive indices of solid bodies, it is necessary to shape them into the form of a prism. Materials with a low melting point usually can be moulded between glass plates. The latter must be plane-parallel and their thickness must be sufficient to resist distortion due to changes in the volume of the melt on solidification. In most cases, cover glasses are too thin, being warped by the contraction of the solidifying melt. When the shrinkage of the melt is such that it separates from the glass plates, it may be necessary to grind and polish the prism. This procedure is obviously unavoidable in many cases where the determination of the refractive index is to be made directly upon a refractory or infusible substance.

Transparent silica glass plates are satisfactory for the construction of prisms of many solid bodies whose melting point is too high to permit the use of ordinary glass. It is frequently possible to make use of cleavage planes in the construction of the prism.

The writer uses a mould of copper to support the glass plates when making prisms from molten materials. The two plane surfaces of the mould are hinged to enable prisms of any angle to be made. A contact goniometer is used to set the mould at the desired angle, clamps being provided to rigidly maintain that position. Plaster of Paris is used to fill the ends and temporarily cement the edge of the glass plates in order to hold the melt. The mould may be gradually heated somewhat below the melting point of the substance and the fused material poured into it. Fragments of the solid material may be melted directly in the heated mould.

When making prisms from highly colored substances it should be rememberd that only the thinnest part of the prism is sufficiently transparent to permit the determination of the refractive index. In any case, the amount of material required for the determination is very small.

Pure compounds, or solutions possessing an abrupt melting point, tend to give sharper readings on the refractometer than viscous liquids or solid substances with a long softening range.

MEASUREMENT OF THE PRISM ANGLE

The refracting angle θ of the prism can be measured by means of the refractometer, by using the method employed to adjust the plane-parallel glass plate to the normal position. The prism is mounted on the plane-parallel plate, using a drop of water or oil between them. Monochromatic light is supplied by grazing incidence at the lower surface of the plate and the refracting edge of the prism is oriented parallel to the axis of rotation of the telescope. The angle R of the ray emerging from the prism is measured as described in an earlier paragraph. The exact position or orientation of the prism at the time of the measurement of the angle R, is retained and not disturbed during the determination of the prism angle θ.

During the measurement of the prism angle θ, the refractometer is supplied with light solely at the small window on the side of the telescope. The telescope is inclined until the image of the window W reflected from the upper surface of the prism coincides with the image E. (See Figures 5*b* and 5*c*). Since the other surface of the prism is parallel to the glass plate, (the normal position) the prism angle θ is read directly from the scale on the graduated sector.

RECIPROCALS OF SINES

Sin 16°	0′—3.62845	Sin 23°	0′—2.55951
	10′—3.59195		10′—2.54194
	20′—3.55619		20′—2.52461
	30′—3.52113		30′—2.50815
	40′—3.48675		40′—2.49128
	50′—3.45304		50′—2.47463
Sin 17°	0′—3.41997	Sin 24°	0′—2.45881
	10′—3.38753		10′—2.44260
	20′—3.35683		20′—2.42718
	30′—3.32557		30′—2.41138
	40′—3.29489		40′—2.39636
	50′—3.26584		50′—2.38095
Sin 18°	0′—3.23625	Sin 25°	0′—2.36630
	10′—3.20718		10′—2.35128
	20′—3.17965		20′—2.33699
	30′—3.15159		30′—2.32288
	40′—3.12402		40′—2.30894
	50′—3.09789		50′—2.29463
Sin 19°	0′—3.07125	Sin 26°	0′—2.28102
	10′—3.04599		10′—2.26757
	20′—3.02024		20′—2.25428
	30′—2.99581		30′—2.24115
	40′—2.97177		40′—2.22816
	50′—2.94724		50′—2.21533
Sin 20°	0′—2.92398	Sin 27°	0′—2.20264
	10′—2.90023		10′—2.19010
	20′—2.87770		20′—2.17770
	30′—2.85551		30′—2.16591
	40′—2.83366		40′—2.15378
	50′—2.81136		50′—2.14179
Sin 21°	0′—2.79018	Sin 28°	0′—2.12993
	10′—2.76932		10′—2.11864
	20′—2.74876		20′—2.10704
	30′—2.72851		30′—2.09556
	40′—2.70856		40′—2.08464
	50′—2.68889		50′—2.07340
Sin 22°	0′—2.66951	Sin 29°	0′—2.06271
	10′—2.65041		10′—2.05170
	20′—2.63158		20′—2.04123
	30′—2.61301		30′—2.03087
	40′—2.59471		40′—2.02020
	50′—2.57666		50′—2.01005

Sin 30° 0′—2.00000
10′—1.99005
20′—1.98020
30′—1.97044
40′—1.96078
50′—1.95122

Sin 31° 0′—1.94175
10′—1.93237
20′—1.92308
30′—1.91388
40′—1.90476
50′—1.89573

Sin 32° 0′—1.88715
10′—1.87829
20′—1.86986
30′—1.86116
40′—1.85254
50′—1.84434

Sin 33° 0′—1.83621
10′—1.82782
20′—1.81984
30′—1.81192
40′—1.80375
50′—1.79598

Sin 34° 0′—1.78827
10′—1.78063
20′—1.77305
30′—1.76554
40′—1.75809
50′—1.75070

Sin 35° 0′—1.74338
10′—1.73611
20′—1.72921
30′—1.72206
40′—1.71497
50′—1.70823

Sin 36° 0′—1.70126
10′—1.69463
20′—1.68776
30′—1.68124
40′—1.67448
50′—1.66806

Sin 37° 0′—1.66168
10′—1.65536
20′—1.64880
30′—1.64258
40′—1.63639
50′—1.63026

Sin 38° 0′—1.62417
10′—1.61812
20′—1.61238
30′—1.60642
40′—1.60051
50′—1.59464

Sin 39° 0 —1.58907
10′—1.58328
20′—1.57778
30′—1.57208
40′—1.56666
50′—1.56104

Sin 40° 0′—1.55569
10′—1.55039
20′—1.54512
30′—1.53988
40′—1.53445
50′—1.52929

Sin 41° 0′—1.52416
10′—1.51906
20′—1.51423
30′—1.50921
40′—1.50421
50′—1.49925

Sin 42° 0′—1.49454
10′—1.48965
20′—1.48500
30′—1.48017
40′—1.47558
50′—1.47080

Sin 43° 0′—1.46628
10′—1.46177
20′—1.45730
30′—1.45264
40′—1.44823
50′—1.44383

Sin 44°	0′—1.43947	Sin 47°	0′—1.36724
	10′—1.43534		10′—1.36370
	20′—1.43102		20′—1.35999
	30′—1.42674		30′—1.35630
	40′—1.42248		40′—1.35281
	50′—1.41844		50′—1.34916
Sin 45°	0′—1.41423	Sin 48°	0′—1.34571
	10′—1.41004		10′—1.34210
	20′—1.40607		20′—1.33869
	30′—1.40193		30′—1.33511
	40′—1.39801		40′—1.33174
	50′—1.39412		50′—1.32837
Sin 46°	0′—1.39024		
	10′—1.38619		
	20′—1.38236		
	30′—1.37855		
	40′—1.37476		
	50′—1.37099		

GEMS AND GEM MINERALS OF NORTH CAROLINA*

JOSEPH HYDE PRATT

North Carolina is one of the more notable states in this country for its variety of gems and gem minerals that have been found and mined within its borders.

With perhaps very few exceptions, the gem minerals have been found incidentally in a search for other minerals, or in the commercial mining of these, such as gold, corundum, mica, and monazite. There have been, however, certain localities that, after the discovery of the gems, have been developed and worked for the gem material.

The variety of gem minerals found in North Carolina is probably greater than in any other state, and includes the following:

- Diamond
- Spodumene
  - Hiddenite
  - Kunzite
- Corundum
  - Ruby
  - Sapphire
  - Oriental Emerald
  - Oriental Amethyst
  - Oriental Topaz
  - Pink Sapphire
  - Asteriated Sapphire
- Beryl
  - Aquamarine
  - Emerald
  - Emerald Matrix
  - Golden and Yellow
  - Blue
- Garnet
  - Almandite
  - Essonite
  - Pyrope
  - Rhodolite
  - Spessartite
  - Uvarovite
  - Jasper
- Opal
  - Hyalite
- Feldspar
  - Oligoclase
  - Orthoclase
  - Microcline
  - Labradorite
- Zircon
  - Hyacinth
- Cyanite
  - Blue
  - Green
- Spinel
  - Ruby
  - Grahnite
- Zoisite
  - Thulite
- Olivine
  - Peridot
- Epidote
- Iolite
- Serpentine
- Malachite
- Titanite

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* Paper read before the Southern Appalachian Mineral Society, Asheville, June 25, 1932.

- Quartz
  - Rock Crystal
  - Amethyst
  - Citrine
  - Smoky
  - Rose Quartz
  - Prase and Chrysoprase
  - Rutilated
  - Agate
  - Chalcedony
  - Carnelian
  - Moss Agate
  - Sphene
- Rutile
- Octahedrite
- Cassiterite
- Hematite (in quartz)
- Pyrite
- Bronzite
- Hypersthene
- Pyroxene
  - Diopside
- Tourmaline (black)

Diamond

Twelve diamonds have been found in North Carolina, and there are also extensive deposits of itacolumite, the supposed matrix of the diamonds from Brazil, and peridotite, the matrix of the South African diamonds. It was hoped and expected that diamonds would be found in the peridotite but very careful examination of these rocks, and panning of the gravel of the streams below them, have not disclosed any diamonds.

The diamonds that have been found in the state occur distributed over a wide area in Burke, Cleveland, Lincoln, McDowell, Mecklenberg, and Rutherford Counties in the western Piedmont section of the state, and in Franklin County on the eastern edge of the Piedmont. They have been recorded from the following localities.

Three diamonds have been found in Burke County, two of which were from near the "Ford of Brindletown Creek." One of these found in 1843 was a well developed octahedral crystal and was valued at $100.00. The third diamond cut a gem 5/16 carat in weight, but its exact locality is unknown. This diamond is now in the State Museum.

The Cleveland County diamond was found in 1893 near Kings Mountain, the crystal weighing approximately $\frac{3}{4}$ of a carat. The Lincoln County diamond was found near Cottage Home by Dr. C. L. Hunter in 1852, in gold washings. This diamond was an octahedron with a greenish tinge and weighed one-half of a carat.

Four or five diamond crystals have been found in McDowell County, two or three of these were very small and were found in 1886 in the gravels at the headwaters of Muddy Creek. The largest diamond found in the state was a twinned octahedron weighing $4\frac{1}{3}$ carats, perfectly transparent, but of a greenish tinge, which was obtained at Dysartville. This diamond is in the American Museum of Natural History, New York City. Another diamond, weighing $2\frac{3}{8}$ carats, was also found near Dysartville in 1877.

A white octahedral diamond weighing one carat was found in 1852 on Todd's Branch, Mecklenberg County; another was found at the J. D. Twitty Gold Placer Mine, Rutherford County in 1845. This was an octahedron with a yellowish tinge, weighing $1\frac{1}{3}$ carats. Two diamonds have been found in Eastern North Carolina in the gravels from the Portis Gold Mine in Franklin County.

In several instances supposed diamonds have turned out to be transparent colorless zircons.

It may be of interest to note here that examinations were made of the peridotite rocks and the gravels in the stream beds below these rock formations, not only for diamonds, but for platinum as well, but none has thus far been found. The only platinum mineral thus far discovered in the state has been a few crystals of sperrylite, which were obtained from the concentrates of the ruby bearing gravels of Cowee Creek, Macon County.

CORUNDUM

There is no state or country that excells North Carolina in its variety of corundum gems. They are colored ruby red, sapphire blue, dark blue, various shades of green, violet, purplish, rose, pink, brown, yellow, grey, and colorless. The corundum gems are classified by their color, and there are at present nine varieties that are commonly recognized by lapidaries.

Most of the corundum found in North Carolina is associated with basic magnesian rocks such as peridotite, pyroxenite and amphibolite. While there are many localities in which corundum occurs, there are but few localities where it is found as gem material. The locality that has furnished the greatest variety of these corundum gems is the Corundum Hill Mine at Cullasaja, Macon County. The opening of this mine by Mr. Chas. W. Jenks in 1871 was the first systematic attempt to mine gems within the state. While the operations were of great interest from a scientific point of view, the number of gems found were so few that permanent operations were not warranted for gems alone, and in a few years the mining of this mineral was for abrasive purposes only. This mine is in an area of peridotite (dunite) of some ten acres in extent. The openings were for the most part along the contact of the dunite with the gneiss or schist through which it penetrated.

At the Corundum Hill Mine practically every shade and variety of corundum gem has been found and cut into precious stones. Perhaps the finest oriental emerald (green sapphire) ever found in the world came from this mine, and is a crystal 4 x 2 x 1½ inches, part of which is transparent and from which several very fine stones could be cut. This crystal is now in the Morgan-Bement Collection in the American Museum of Natural History, New York City. Two of the best rubies that were ever found in this mine are also in this same collection.

A blue sapphire of over one carat in weight and a series of fine red and blue crystals are in the U. S. National Museum at Washington. Also in the National Museum are several beautiful gems from this same mine that were formerly in the Leidy Collection in Philadelphia, and include a wine yellow sapphire of 3¼ carats, a violet blue sapphire of a little over one carat, and three dark blue stones weighing respectively 1½, 1¼, and ¾ carats each.

The most noted ruby locality is on Cowee Creek, north of Franklin, Macon County. The ruby corundum at this locality occurs in an entirely different rock from that in which the corundum gems occurred at the Corundum Hill Mine. The Cowee rubies occur in what is probably a basic hornblende-gneiss, and amphibolite. Some very fine rubies equal in color and quality to the Burma rubies have been found at this locality. They are of the well-known "pigeon blood red" color. The finest piece of ruby was a rough hexagonal crystal that measured about one inch by one and one-half inch. It was estimated that from the transparent portion of this crystal a gem worth from $1500.00 to $2500,00 could be cut. Although every endeavor was made to keep down expenses in mining these rubies, it was never a profitable mining proposition. The percentage of the ruby corundum that was capable of being cut into gems was too small.

Another locality from which several very good rubies have been obtained is the Grimshawe Mine near Montvale, Jackson County. To the north of the Corundum Hill Mine, and across the ridge is the Ellijay Mine on the headwaters of Ellijay Creek. At this mine a few very fine pieces of ruby corundum have been found, from which several exquisite gems have been cut.

Other mines besides the Corundum Hill Mine that have furnished good sapphires, are the Sapphire and White Water Mines near Sapphire, Jackson County, and the Grimshawe Mine at Montvale.

Many of the other corundum localities in North Carolina contain corundum of a deep blue color, but are not sufficiently transparent to be of value for gem purposes.

Another interesting variety of sapphire corundum occurring at the Corundum Hill Mine is a banded blue and white corundum. One gem was cut from this banded material which made rather an attractive sapphire of a rich deep blue color, but with a band of white or colorless material in the center.

At the Ellijay mine referred to above, the principal corundum found is a peculiar brown or bronze variety, which is known locally as "pearl corundum." This corundum shows distinct asterism both by natural and artificial light when cut cabochon. The fresh fracture of this corundum shows a decided bronze lustre and is somewhat similar to cat's eye. When cut the eye is sometimes very distinct. Cut gems as much as two-thirds of an inch in diameter have been obtained from this corundum.

Another attractive corundum is the pink and ruby corundum in masses of emerald to grass green amphibolite (smaragdite) which is found at the Cullakeenee Mine, Buck Creek, Clay County. While the corundum is not of gem quality, the combination of the green and pink colors make very beautiful specimens which take a high polish, and might make an ornamental stone of some value. It has been used to a limited extent for such purposes under the name of "Ruby Matrix." Near Elf post office on Shooting Creek, Clay County, there is a similar occurrence of pink corundum and sometimes a blue in amphibolite.

BERYL

The mineral beryl is found usually in pegmatite veins or dikes, which mineralogically constitute some of the most interesting and attractive occurrences in the state. Forty-seven different minerals have been noted from these pegmatites, and as many as twenty minerals have been found in a single vein.

Of the minerals found in pegmatites the following have been noted with sufficient purity to be a source of gems: beryl (aquamarine, blue, yellow, and emerald), oligoclase (moonstone), orthoclase (sunstone), microcline (amazonstone), quartz, garnet (essonite, rhodolite and almandite), gahnite (a green spinel), rutile, cyanite, and zoisite (thulite).

EMERALD. There are many beryls which have a light green or a rather deep yellowish green color, but few have the rich deep emerald green, so highly prized in the gem variety, and which is due to a minute amount of the oxide of chromium.

There are three localities in North Carolina where the real emerald beryls have been found, one in Alexander County in the vicinity of Hiddenite and Stony Point; the second in Mitchell County, near Spruce Pine; and the third in Cleveland County, a few miles south of Shelby.

The Alexander County emeralds are found in "gem-bearing pockets" which vary from several inches wide and a foot or more in length, to some that are a foot in width and several feet in length. Lining the sides of these cavities are several other minerals besides the emeralds and hiddenites, such as: quartz, aquamarine, rutile, dolomite, calcite, apatite, pyrite, monazite, and very beautiful muscovite crystals. All these minerals are extremely well crystalized. Occasionally the hiddenite crystals are found loose in the cavities.

The largest emerald crystal found during these mining operations was 8½ inches in length, and weighed nearly nine ounces. It is now in the Morgan-Bement Collection in the American Museum of Natural History. Eight other emerald crystals were found in the same pocket, all of excellent color but only partially transparent. One was 5 inches in length and several others over three inches. Many gems have been cut from the product of this mine. Two others, one 4-23/32 carats and another 5 carats in weight, were somewhat too light in color to rank as very fine gems. These and a series of smaller emeralds are also in the Morgan-Bement Collection.

Many other crystals of emerald one to three inches in length have been obtained; and emeralds are still being found occasionally by the farmers in the area extending in length from one mile southwest of Stony Point to Hiddenite, and for several miles in width.

The Cleveland County emerald locality is on the land of W. B. Turner, 4¾ miles southwest of Shelby, and near the east bank of First Broad River. The largest emerald found was part of a crystal that measured one inch by ¾ inch. It was estimated that about 2700 carats of rough emeralds were produced in the mining operations of this property; and that from this 700 carats of cut gems were obtained, which were valued at $5.00 to $200.00 per carat.

The Mitchell County locality that has furnished gem quality was discovered in July 1894, and is 14 miles from Bakersville and about the same distance from Mt. Mitchell on Big Crab Tree Mountain. The emerald occurs in a pegmatitic vein about 5 ft. wide. The associated minerals include translucent reddish garnet, black tourmaline, and aquamarine. The emeralds are small but well crystallized, varying in size from one to ten millimeters in width and five to twenty-five millimeters in length. They are of a very fine emerald green color, but only occasionally are they transparent enough to cut into faceted stones.

This property was operated by the American Gem and Pearl Company of New York, who developed a new gem material by cutting the emerald bearing rock (emerald, quartz, and feldspar with occasionally some tourmaline) en cabochon, and calling the cut stone "Emerald Matrix." The green and white mixture with an occasional bit of black color was very pleasing and this gem stone had considerable sale.

AQUAMARINE. The aquamarine variety of beryl is found quite commonly in many of the mica mines and pegmatitic dikes of Avery, Cleveland, Mitchell, Yancey, and Alexander Counties, and to a less extent in the mines and pegmatite dikes of Rutherford, Haywood, Jackson, Macon, and Transylvania Counties.

The principal localities are: The Wiseman Mine, near Spruce Pine, and the Grassy Creek locality in Mitchell County; the Ray Mica Mine near Burnsville, Yancey County; the Littlefield Mine on Tessentee Creek, near Highlands, Macon County; the R. E. Brown prospect, and the Grimshawe Mine, Jackson County; the Hiddenite and Stony Point deposits and the prospects near Healing Springs, Alexander County; the Hollybush prospects near Shelby, Cleveland County; and the Joel Walker prospect on South Mountains, Burke County. From all these localities gems of exceptional beauty have been obtained.

HIDDENITE

Hiddenite, a variety of spodumene, is a mineral peculiar to North Carolina. Specimens of the crystals and of cut stones of this gem mineral are in all the important collections, and the cut stones today are considered in value equal to that of the diamond. A 2½ carat stone was sold for $500.00, and a number of other stones have brought from $40.00 to $100.00 per carat. One of the finest hiddenite crystals is in the Morgan-Bement Collection. It measures 2 2/5 by ½ by ⅓ inch, and it is estimated that from it there could be cut a gem weighing 5½ carats.

Mr. Burnham Colburn operated the mine in 1927 and obtained what is now probably the finest collection of hiddenite in the world. This material is in his museum in Biltmore Forest, N. C.

GARNET

The different varieties of garnet that have been recognized in North Carolina are: grossularite (essonite), pyrope, rhodolite, almandite, spessartite, and andradite (demantoid).

Of the above the essonite, pyrope, rhodolite, and almandite are used for gem purposes.

The essonite garnet, which is also known as cinnamon garnet, or cinnamon-stone and is the "hyacinth" of the jeweler, has been found in beautiful transparent flat crystals between plates of mica in the mica mines near Bakersville, N. C., some of which were cut into gems of a carat or more in weight.

The almandite is the commonest of the gem garnets, and varies in color from a pinkish or scarlet, through brownish red to occasionally a deep red. This garnet has been found very extensively in Burke, Caldwell, Catawba, Jackson, and Mitchell Counties. Some almandite garnets have been found that weighed as much as 20 lbs. but they were not of sufficient purity to be cut into gems. At a great many mica mines in Avery, Mitchell, and Yancey Counties this garnet has been found crystallized in blocks and sheets of mica, and is usually perfectly transparent.

The pyrope garnet, which is also known as Bohemian garnet, has a more blood-red tint than the almandite. Pyrope of good color has been found in sands of the gold washings of Burke, McDowell, and Alexander Counties.

The rhodolite is the most unique variety of garnet found in North Carolina, and thus far has not been found in any other state. After it was recognized and named, it became commercially the most valuable gem material produced in the state. It has a variety of shades of color which are, for the most part, similar to the delicate rose-like tint of one of the rhododendrons. Most varieties of garnets are only beautiful and brilliant by transmitted light, and otherwise exhibit dark shades of color, but the rhodolite gives very striking effects of beautiful and varied colorings by reflected light. When first discovered the rhodolite was mistaken by many, and even by some jewelers, for a variety of ruby, and not until it was tested and analyzed would they believe otherwise.

The rhodolite has only been found in a very limited area, which includes the gravels of the streams that rise on Mason Mountain in Macon County, and in the gneissic rocks in several places on this mountain. Beautiful gems have been cut varying in size from a fraction of a carat to as high as 13⅜ carats in weight. The largest piece of rhodolite that is recorded weighed 43½ carats.

QUARTZ

Of the quartz gems the amethyst is the most beautiful and perhaps the most desired. There are many localities in Haywood, Macon, Catawba, Iredell, Lincoln, Davidson, Franklin, Wake, and Warren Counties where amethystine quartz occurs in considerable quantity, and in several of these localities it is of the beautiful purple shade, clear and transparent.

The best amethysts have been found in Macon, Lincoln and Catawba Counties. The Macon County deposits are on the headwaters of Tessentie Creek, and when the property was operated by the American Gem and Pearl Company in 1906, some of the most beautiful amethysts ever found in this state were obtained. Although many of the localities do not furnish amethysts suitable for cutting, they do produce very beautiful and interesting mineralogical specimens.

At Taylorsville, and Stony Point, Alexander County, extremely beautiful smoky quartz crystals have been obtained, and some of these have afforded fine gems. They are generally from one to 5 inches in diameter, and sometimes of a citron or light yellow color. From a mineralogical standpoint, the smoky quartz crystals from near Hiddenite and Stony Point, have attracted attention of mineralogists on account of the fact that the crystals are highly and peculiarly developed.

Perfectly transparent rock crystal is used to a considerable extent for cutting crystal balls, cubes and other objects of art. Some of the best rock crystal has been obtained from Long Shoals Creek on a spur of Phoenix Mountain in Chestnut Hill Township, Ashe County. Perfectly transparent spheres 4½ inches in diameter, and slabs 6 inches square and from ½ to 1 inch thick have been cut from this quartz. Rock crystal from Alexander County has furnished spheres 2 to 2½ inches in diameter, and that from Burke County 2 3/16 inches in diameter. Similar material has been found near Elkin, Surry County, and near Bakersville, Mitchell County.

Another variety that is interesting is rutilated quartz, also known as sagenite or venus hairstone, which has been found in many places in Randolph, Catawba, Burke, Iredell, Jackson and Alexander Counties. Citrine or Spanish topaz, has been found with good color near Taylorsville, Alexander County, and in Burke and Catawba Counties. Rose quartz has been found near Dan River, Stokes County, and in Iredell and Catawba Counties.

The cryptocrystalline varieties of quartz, with the exception of chalcedony, have not been found to any large extent in North Carolina. Chalcedony of a rich fawn and salmon color has been obtained near Linville, Avery County; and fine agates and chalcedony were reported from Caldwell, Mecklenberg County; near Harrisburg and Concord, Cabarras County; and in Granville and Orange Counties.

The chrysoprase or prase variety of chalcedony, has been found in Buncombe County, near Morgan Hill, about 16 miles from Asheville. At the surface the color was pale green but the tint became deeper and richer as the mineral was obtained from lower depths. Prase of a rather light green color has also been found on Tremont Mountain to the west of Franklin, Macon County.

The jasper variety of quartz is found in Granville and Person Counties in banded red and black streaks; a bright brick red and yellow variety is reported at Knapps on Reed Creek, Madison County; at Shut-in Creek in Moore County; and in Wake County.

Opal

The hyalite variety of opal has been found at the Corundum Hill Mine, Macon County; the Carter Mine, Madison County; near Concord, Cabarras County; and near Elf, Clay County; but in no instance can it be considered as gem material.

Feldspars

There are several interesting varieties of feldspar occurring in North Carolina, from which some very beautiful gems have been obtained.

The most interesting of these feldspars and the one that has furnished the most beautiful gems is oligoclase, variety moonstone. This occurs at many of the mica mines in Mitchell and Avery Counties, but it is the Hawk Mine four miles east of Bakersville, that has furnished the best material, which is remarkable for its transparency. One clear piece was found which measured 1×2×3 inches.

The orthoclase feldspar, variety sunstone, has been found near Statesville, Iredell County, and at Gold Hill, Rowan County. From each of these localities material was obtained which furnished material for gem purposes.

The microcline feldspar of a very beautiful light green color, known as amazonstone, has been found in North Carolina, at the Ray Mica Mine in Yancey County. Labradorite has been found near Charlotte, Mecklenburg County, and near Bakersville, Mitchell County. While the mineral from these localities shows a slight blue chatoyancy, it is not nearly as beautiful as the labradorite from Labrador.

Other Gem Minerals

Zircon or hyacinth as it is sometimes known, occurs quite abundantly in very small crystals in the gold and monazite sands of Polk, Burke, McDowell, Rutherford, Caldwell, Lincoln, and Cleveland Counties. Very few of these crystals have thus far been found of sufficient size to cut into gems.

Beautiful crystals of zircon, but not of gem quality, have been found at Sterling Hill, Iredell County, near Tuxedo, Henderson County, and near Mars Hill, Madison County.

Rutile is one of the most interesting minerals found in North Carolina, and reference has already been made to its occurrence as hair-like crystals in quartz. The color of rutile varies from deep red or reddish brown to black, and that from Alexander County has furnished some very fine cut black rutile, which closely approaches the black diamond in appearance. Rutile has been found quite widely distributed throughout the state in Alexander, Iredell, Burke, Macon, Madison, Swain, Orange, and other counties.

Cyanite has been found of gem quality in several localities in the state. The gem material occurs in two colors, one a deep blue and the other a moss green. Fine blue crystals of cyanite occur near Crowder's Mountain, Gaston County; near Swannanoa Gap, in Buncombe County; on Yellow Mountain, Mitchell County; and near Micaville, Nancy County. The green variety is found on the Young farm on North Toe River, a few miles from Spruce Pine, Mitchell County. Crystals are often transparent and were found up to $\frac{1}{2}$ inch in diameter and over one inch in length.

The mineral olivine, variety peridot, occurs very abundantly throughout North Carolina as a constituent of peridotites. The most promising localities in North Carolina for olivine of gem quality are near Webster and Balsam Gap, Jackson County.

Serpentine occurs widely distributed throughout the western section of the state and is usually the result of the alteration of some of the basic magnesian rocks. There are only a few localities where the translucent, green variety known as precious serpentine occurs. These are in the outcrops of the basic magnesium rocks between Leicester and Weaverville, Buncombe County; in Madison and Yancey Counties; near North Wilkesboro, Wilkes County; and near Patterson, Caldwell County.

The pink or rose colored zoisite, known as thulite, is found in radiating crystals in several of the mica mines in Avery and Mitchell Counties, associated with feldspar. In 1908, thulite was found at the Flat Rock mica mine, Mitchell County, which furnished some attractive gems when cut en cabochon with the inclosing feldspar.

Black tourmaline is found very commonly in many of the mica mines of Avery, Mitchell, and Yancey Counties; and sometimes it is in well developed terminated crystals. Occasionally it has been found crystalized in blocks of mica. Transparent green crystals of tourmaline have been reported from near Waynesville, Haywood County.

Octahedrite, in thin tabular brilliant crystals of a pale green color and up to one-third inch in diameter, has been found in the sands of Brindletown Creek and elsewhere in Burke County. Such crystals might furnish material from which gem stones could be cut.

Malachite occurs in small quantity at many of the copper mines of the state; but only rarely has it any gem value. A few fine pieces of gem malachite were obtained at the Copper Knob Mine in Ashe County and were placed in the Torrey Collection at the U. S. Assay office in New York City.

Of the remaining minerals referred to in the list of gem minerals occurring in North Carolina, attention might be called to the following:

Green gahnite and iolite from the Cowee ruby mine, Macon County; titanite, from the zircon mine near Tuxedo, Henderson County; hematite in quartz, from Iredell County; bronzite from near Webster, Jackson County; and epidote from Hampton's, Yancey County, near Old Fort, McDowell County, and from the gold gravels of Rutherford County.

MICROSCOPIC MINERALS OF THE CLAYS OF MIDDLESEX COUNTY, NEW JERSEY

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During the detailed microscopic study of the clays and accompanying sands of the Cretaceous Raritan formation in Middlesex County, New Jersey, by the senior author of this paper, numerous interesting crystallized minerals have been observed. Search for their possible genesis and place of origin forms part of a fascinating problem in sedimentary petrography and stratigraphy, concerning which more will be published in the future.

This research has been done with a Leitz petrographic microscope, using a magnification, for the most part, of 331 diameters. Various representative clays from the Raritan formation have been elutriated by washing through three containers having different known rates of water flow. Thus the sand and heavy minerals have been separated from the clay which carried them, and the quantitative amounts and relative abundance of the various minerals in each clay determined. It is within the scope of this paper merely to describe the minerals which are present in the clays and associated sands.

The sands of this region of the inner part of the coastal plain belong to the Cretaceous series and alternate with the clays beds. The grains of the sand, which are mostly quartz, (though one sand lens was locally almost a pure dolomite), are found to vary in size from 0.05 mm. to 1 mm., with some which are larger. The sand grains are remarkably angular and show little attrition. Some sands are full of tiny plates of muscovite in practically unaltered condition. There are lenses in the uppermost sand containing microcline, and even granitic fragments still clinging together; and an origin in the granite gneisses of the highland belt of New Jersey and southern New York is plainly indicated. A very few grains of plagioclase, of the acid type, are rarely found. The lower sand, though for the most part pure quartz, contains splintery magnetite fragments, and ilmenite in plates and angular pieces of all sizes, but usually about 1/10 the size of the quartz grains which are with them. There are also magnetite grains which are spherical and look like shot. Where the sands are dry, fresh pyrite in beautiful little crystals is quite abundant; where water is present, the sand is full of colloidal limonite. Chlorite is frequently noted, and a few grains of hornblende in some strata; epidote in broken fragments is encountered at times, and even perfect green octahedrons of spinel, probably derived from the crystalline limestones of the Franklin Furnace-Amity belt. Red hematite in translucent plates; zircon which is colorless, pink, or brown; tourmaline, in small crystals, and fragments of larger ones; also tourmaline crystals which are still in quartz or mica grains; rusty biotite, and carbon, all are present. Garnets are practically absent, apparently because garnets are brittle and break up during transportation or change to limonite; those which have been found are dodecahedral or trapezohedral.

The study of the elutriated residues from the clays shows that the size of grain of the sandy material in the clay is from 0.01 mm. to 0.05 mm. in diameter, with very little that is coarser. Thus the finer grades of fire clay contain no grit of size large enough to be clearly felt between the fingers. On the other hand, there are, of course, gradations from pure clays through sandy clays to clay-bearing sand. The mineral grains here described are usually of a diameter like that given above. The shape of the grains of quartz and of the heavy minerals is remarkably angular and there are few signs of any prolonged attrition; quiet deposition is clearly indicated.

The plastic clay body is composed of kaolin in grains of the order of 0.001 mm. in diameter. With the kaolin is a variable amount of micaceous material in tiny grains and shreds, often making up nearly 50% of the clay body. This mica is partly muscovite and partly a hydrated mica, the ratio being 50%, more or less, of each.

The minerals found in the elutriated clay residues are of numerous species, representing those of all of the rocks of the region within perhaps 200 miles to the north and west of Middlesex County. Some of the best examples of those in crystalline form are illustrated in Plate I. They are as follows:

Magnetite (Fig. 1) is occasionally seen in small, sharp octahedrons. Some of these may possibly be chromite derived from the serpentines. Most of the magnetite, however, is in splinters and fragments. It is common in the lower sand (sand No. 1) and in the Raritan fire clay below this sand, but is uncommon in the Woodbridge fire clays and in the upper sand (sand No. 2) above the latter clays.

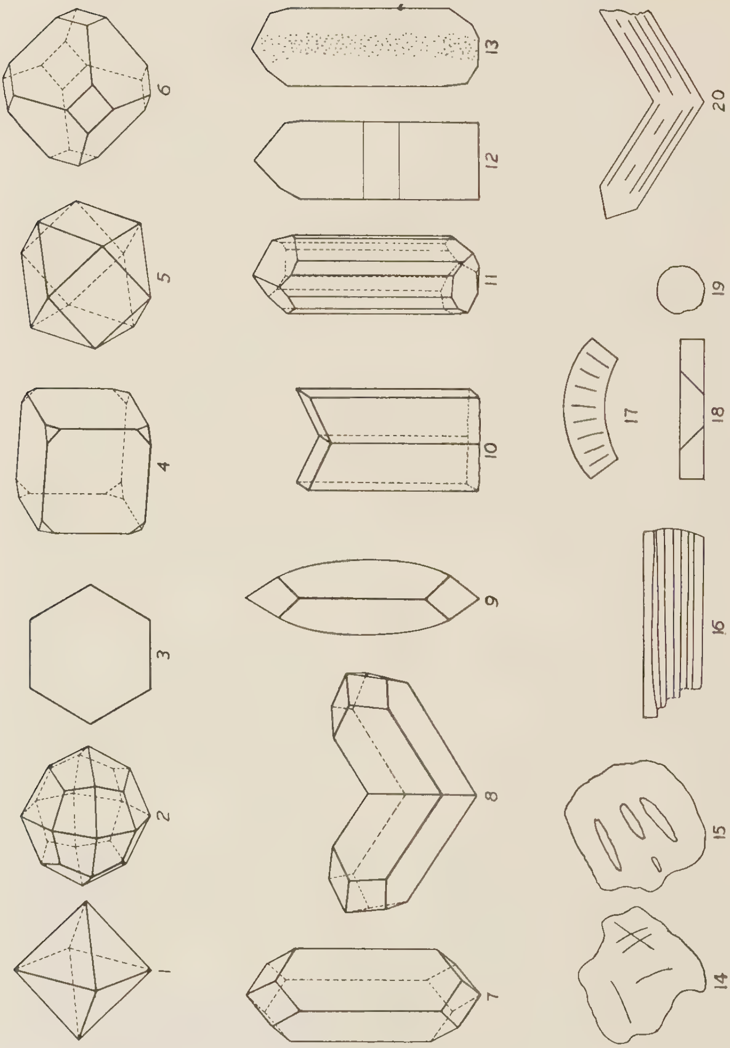

PLATE 1

Garnet (Fig. 2) is uncommon in all of these clays and sands; some grains and crystals are found in the Raritan fire clay at the base of the series. The figure shows such a crystal with the form of the trapezohedron (211); it is also occasionally present in dodecahedrons. Its origin is in the various crystalline rocks which are garnetiferous, including the ancient schists of the Manhattan belt and the granite gneisses of the highlands.

Hematite (Fig. 3) often has a clear red color, and plates with a sharply defined hexagonal outline are not uncommon. Part of it at least has been of secondary origin in the clays.

Pyrite (Figs. 4, 5, 6) is a secondary mineral in the clays. Forms observed include the cube, the octahedron, and various combinations between these. Combinations as well as simple cubes and octahedrons, may occur together in one small clay sample. This is true of the clay from the Quigley property on the south side of the town of South River (pyrites visible under high power only). The pyritohedron is a rare form on pyrite from these clays, having been but once observed (pyritohedron *e* (210)) on pyrite from Sayreville. In this case the form was a small modification on a cubo-octahedron. In some cases, tiny balls and crystals of pyrite are regularly oriented on the edges, or corners, or both, of hematite or ilmenite plates. Marcasite, though found as spearhead twins a half inch long in the Woodbridge fire clay in the vicinity of Parlin, has not been identified among the microscopic minerals.

Zircon (Figs. 7, 8, 9) can be found in the clays and sands in microscopic crystals and grains of three distinctly different kinds, viz.: There are colorless crystals (Fig. 7), always showing the first order prism with the second order pyramid (malacon type). Fig. 8 shows a twin, and Fig. 9, a tapering crystal. Examination of the rocks of the surrounding area shows that the zircon crystals of the Manhattan schist series have these characteristics; and it is to this source that their occurrence in the clays must be due. An interesting fact is brought to light by the common occurrence in the clays of zircon grains of this type whose shape is subangular, much rounded, or even spherical. In the absence of any signs of rounding of the quartz grains, it has been difficult to understand why grains of a mineral with such superior hardness, as zircon, should be so rounded. But upon careful examination of the zircon crystals in the original rock, it was found that most of them were incompletely formed, and that, therefore, the shape of the zircon grains in the clays is not due to wear through transportation, but to the original shape of the grains, which were often rounded. There are brown zircon crystals, showing a combination of the first order unit prism with the first order unit pyramid *p*, and often also the acute first order pyramid *u*(331). These crystals are plainly of the type which occur in the crystalline granite gneisses of the highlands, often in the proximity of the magnetite ores. Pink zircon crystals also are not uncommon, which are made up of a combination of the first order prism and unit pyramid; the origin of these crystals has not yet been ascertained.

Gypsum (Fig. 10), more properly described as a pseudomorph of an unidentified mineral after gypsum. These crystals, comprising less than one per cent of the clays in which they occur, have been identified by their angles as measured under the microscope, as having been originally gypsum. They are flattened as usual on pinacoid *b*, and show in addition, prism *m*, unit pyramid *l*, and rarely base *c*. Swallow-tail twins are not uncommon, and also sheaf-like groupings typical of gypsum. But though these crystals polarize with colors, yet their internal structure may best be described as granular crystalline. The crystals appear monoclinic, yet their extinction is practically parallel to the nicols. This leads to the conclusion that the present crystals are either pseudomorphs, or else have changed in water content, and thus taken on the confused inner structure. The refractive indices of the present material are as follows: $\alpha = 1.490$, $\gamma = 1.530$. This shows no correspondence with any known calcium sulphate compound.

Tourmaline (Figs. 11, 12, 13) is probably the most interesting of all the clay minerals, from the point of view of crystallization. There are myriads of these crystals in the clays of Middlesex County, and most of them are of but one type and general size. They are normally about 0.1 mm. long and half to a quarter as wide, and can be seen in any of the clays with the aid of a microscope of very moderate magnifying power. Their crystal forms are prisms *m* and *a*, unit rhombohedron *r*, acute minus rhombohedron *o*, and base *c* (Fig. 11). Others are flattened, as in Figs. 12 and 13. They are green in color, some with yellow terminations, others with transverse bands which are colorless, yellow, blue, or brown (Fig. 12). Nearly all of them carry microscopic dusty black inclusions which are arranged lengthwise in the crystal (Fig. 13). Their uniform size and complete development suggest an origin in metamorphic schists; precisely similar tourmalines are present in great numbers in the Carboniferous schists of central Connecticut and Massachusetts, and in the many other dark colored phyllites and schists of New England, including the Ordovician rocks which were affected by the Taconic uplift in Vermont; hence this is considered to be the region of their origin. Judging by quantitative microscopic measurements of tourmaline content on the clays and the New England rocks, about 3% of the clay material was derived from the tourmaline-bearing schists and phyllites of New England. Thin, flat tourmalines within muscovite plates have been observed in the clay residues, and some of these are grayish blue indicolite, as found in western New Hampshire. A minor number of other small tourmaline crystals with other characteristics are found in clays and sands. There are fragments of larger tourmalines of green and brown colors, particularly in the sands.

Quartz (Figs. 14, 15) is usually in ragged, angular grains, although a relatively few rounded grains, and even a quartz crystal or two, have been observed. A great many of the quartz grains contain dusty inclusions, like those of the granite gneisses, and others contain cavities, often elongated, or needles of rutile or similar acicular minerals (Figs. 14, 15). Zircon and tourmaline crystals are sometimes found in these quartz grains, and in one case there was within the quartz a bright blue mineral, evidently azurite.

Muscovite occurs in the form of shreds and plates of all sizes Much of it is hydrated or otherwise altered.

Kaolin is often in the form of curved aggregates of plates (Fig. 17). These are typical of much kaolin, like that in the granite gneisses of the highlands, and sedimentary rocks derived therefrom, of many different ages. In this form the kaolin may be original or secondary.

Ilmenite, besides appearing in irregular grains, is occasionally seen in distinct plates, the most complete of which show base *c* with prism *m* and unit rhombohedron *r* (Fig. 18). Some ilmenite grains approach a perfectly spherical shape (Fig. 19), which does not appear to be due to abrasion, but to the original shape of the grain.

Rutile (Fig. 20) is in the form of prisms which appear deeply striated; a very few are twinned. The amount of rutile present, however, is very small in proportion to that of ilmenite, from which we conclude that the titanium in the clays is principally in the latter mineral.

Limonite and closely related hydrous iron oxides are present in clays and sands in great abundance; many of their forms are colloidal, while others are strongly crystalline. All stages of derivation from pyrite and the other iron minerals may be observed.

Other minerals which have been seen in a few instances are pyroxene, enstatite, hypersthene, monazite, staurolite, one sharp crystal resembling olivine, and several grains and aggregates occasionally encountered whose exact nature is uncertain. No definite zeolite has been identified.

With the exception of the pyrite crystals and limonite derived therefrom and from other iron bearing minerals, the kaolin aggregates, the gypsum crystals, and the crusts of melanterite and of alum which appear on clay surfaces, it does not seem probable that any of the mineral grains above described have been secondarily produced in the clays since the deposition of the latter.

ZEOLITIC ALTERATION OF PYROCLASTICS

M. N. Bramlette and E. Posnjak*

Abstract

The frequent alteration of vitric pyroclastics to clay materials, of which montmorillonite is the most abundant, has been well established and bentonite is recognized as a rock name for such material. This paper points out that the mineral clinoptilolite, which may be included with the zeolites, is also a common alteration product of pyroclastics where the alteration is less complete. This mineral seems to be an intermediate product in the process of alteration of the volcanic glass, with the clay mineral an end product of the process.

A zeolitic mineral identified as clinoptilolite was observed very commonly in a number of samples of altered pyroclastics from the Miocene of California. The abundance of this mineral and its mode of occurrence seemed significant enough to make an exact mineral determination advisable. The results obtained in the examination of altered pyroclastics from this and other regions suggest that the features here presented may characterize many occurrences.

Many of the beds of pyroclastics in the Monterey group of California, especially in the upper part of the section, are nearly unaltered vitric volcanic ash, the isotropic glass having an index of refraction close to 1.50. Other beds occurring lower in the section show an alteration of the vitric tuffs to a clay mineral with the optical characters of montmorillonite, and some of these retain in part their original vitroclastic texture, as seen in thin section. In other beds the original tuff seems less completely altered, and in thin section the original texture is well preserved with the larger shards appearing nearly isotropic, and only the finer-grained material and groundmass are composed largely of the birefringent clay mineral. In addition there are grains and crystals of a mineral of lower refringence and birefringence than the clay mineral. In certain areas, particularly in bubble cavities, this mineral develops a good crystal form.

On washing down such a sample to eliminate the fine clay mineral, the residue is composed of relict shards retaining many of the characteristic shapes of the original volcanic glass fragments

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and many minute crystals which in part appear penetrating the shards. In this washed residue the thickness of grains is greater than in thin section and thus shows that the shards are also weakly birefringent, and of the same index of refraction as the crystals. Both the shards of microcrystalline aggregates and the anhedral crystals on heating to less than 200° Centigrade, show a marked increase in birefringence and decrease in refringence.

The mineral where showing a good euhedral crystal form has a tabular habit with development of crystal faces similar to those of heulandite, and also to those of clinoptilolite from Wyoming, originally described as mordenite, and reproduced in Dana's System of Mineralogy on page 573. Penetration twinning is frequent and undulatory extinction is general. The mean index of refraction seems somewhat variable but is near 1.480. The axial angle is large, and measurement of the bisectrix angle emerging normal to the flat lying plates seemed considerably above 90°, indicating the obtuse bisectrix. As this bisectrix is Z, the mineral would be

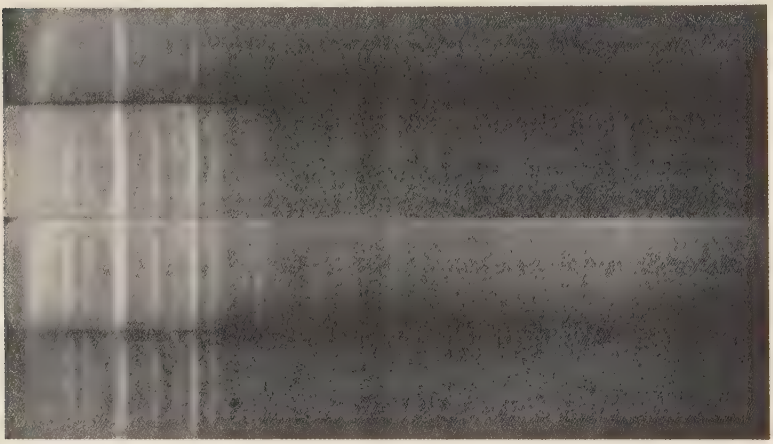

Fig. 1

1. Crystals from Miocene bentonite at Highland Monocline, San Luis Obispo County, California.
2. Clinoptilolite from Wyoming. Type material from original occurrence in Wyoming (described by Pirsson as mordenite).
3. Residue of shard fragments from bentonite, Dome, Arizona (sample analyzed).
4. Heulandite, West Paterson, New Jersey.

negative in optical sign. The mineral is not attacked by warm hydrochloric acid and fuses with difficulty. These properties seem to indicate clinoptilolite, recently named and described by Schaller.[1]

The anhedral aggregates composing the shards show these same properties. *X*-ray examinations by the powder method were made to ascertain whether the euhedral crystals and the microscopic aggregates of the shards were actually identical and further whether this material corresponds to the mineral clinoptilolite. The results showed complete identity of this crystalline alteration product with clinoptilolite. Some typical spectrograms are reproduced (Fig. 1), and a spectrogram of heulandite is included. Comparison of the diffraction patterns of clinoptilolite and of heulandite shows that they are practically indistinguishable. In view of differences in their optical characteristics and chemical composition, as well as possibly some variability in the latter, the most probable assumption for the present seems to be that the two minerals represent members of a series of solid solutions. This, however, is a separate problem which will require further study. It may only be added in this connection that a sample of mordenite, which was supposed to be a part of the type specimen, gave a very different diffraction pattern, and therefore does not seem to belong to the heulandite group of minerals.

The occurrence of clinoptilolite is so common in the altered pyroclastics in the California Miocene that it seemed desirable to determine whether it is of more general occurrence. A sample of bentonite from Dome, Arizona, that was not completely altered to the clay mineral and showed in thin section many relict shards of apparently isotropic glass, was examined. The washed residue, consisting largely of these characteristic shard forms, showed the same optical characters as the mineral from California, and the *X*-ray pattern confirmed the identity. This is one of the samples shown in the spectrogram figure. As this sample was most easily separated and purified, a sample of the clinoptilolite was obtained by washing out of the clay mineral and eliminating the feldspar, etc., by liquid flotation. This sample was analyzed in the chemical laboratory of the United States Geological Survey, by J. G. Fairchild, with the following results:

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[1] Schaller, Waldemar T., The mordenite-ptilolite group; Clinoptilolite, a new species: *Am. Mineral.*, **17**, 128, 1932.

Analysis of clinoptilolite from Dome, Arizona

SiO_2	64.30
Al_2O_3	12.78
Fe_2O_3 (total Fe)	.82
CaO	2.42
Na_2O	3.96
K_2O	1.36
MgO	.62
H_2O-	4.78
H_2O+	9.50
	100.54

In regard to this analysis, Dr. Schaller states: "The analysis of the sample of clinoptilolite, as given, yields the ratios: 8.56 SiO_2: 1.00 Al_2O_3: 1.09 RO(RO = CaO, Na_2O, K_2O, MgO): 6.35 H_2O. While considerably different from the normal formula of heulandite, these ratios are not very close to the formula ($10SiO_2 \cdot 1Al_2O_3 \cdot 1RO \cdot 7H_2O$) of clinoptilolite. However the sample analyzed contained about 5 per cent of clay mineral and if allowance be made for this impurity, the ratios come closer to those of clinoptilolite. The *X*-ray pattern shows that the mineral can not be mordenite."

A sample from Pedro, Wyoming, from the thick bentonite in the basal part of the Pierre shale of the Black Hills region, seemed less completely altered than most of the bentonites of this area, and in thin section shows many of the larger shards as apparently isotropic relict glass fragments in a finer groundmass of montmorillonite. On a similar examination of the washed residue, these shards appeared to be the same mineral though in finer cryptocrystalline aggregates, and *X*-ray patterns (not reproduced here) confirmed this material as clinoptilolite. In this sample from the Pierre shale, the crystal phenocrysts consist of an andesine-labradorite plagioclase and euhedral crystals of biotite and apatite and some magnetite, but with no quartz or orthoclase. In the other samples examined the phenocrysts are less abundant but consist of a sodic plagioclase, orthoclase, quartz and minor amounts of zircon. This suggests that the Pierre bentonite was derived from a somewhat more calcic glass, though it gave the same alteration products.

Alteration of volcanic rocks resulting in the formation of a zeolite has been described by various writers, and an occurrence in the Green River formation, described by Bradley,[2] has some features in common with the results here presented, though the resulting zeolite was analcite with some apophyllite. It now appears from the results of this investigation that an alteration of pyroclastics to clinoptilolite is very widespread, though the recognition and positive identification of the mineral offers difficulties.

The relations strongly suggest that this clinoptilolite is an intermediate stage in the process of alteration that finally results in a typical bentonite composed of a clay mineral, though it is not implied that all bentonites have gone through such an intermediate stage. The chemical composition of the mineral is close to that of an alkalic volcanic glass, whereas the composition of a bentonite composed of montmorillonite shows a distinct loss in silica and alkali, with a relative increase in alumina and magnesia. These chemical relations would seem to support the view that the zeolite is an intermediate product and the clay mineral a later stage of more complete alteration.

The writers wish to acknowledge the helpful advice and criticism of Dr. W. T. Schaller and Dr. C. S. Ross of the United States Geological Survey, of Dr. C. N. Fenner of the Geophysical Laboratory, and to express their thanks to John G. Fairchild for making the chemical analysis.

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[2] Bradley, Wilmot H., The occurrence and origin of analcite and meerschaum beds in the Green River formation of Utah, Colorado, and Wyoming: *U. S. Geol. Survey, Prof. Paper* **158,** pp. 1–7, 1929.

NOTES AND NEWS

NOTE ON THE STRUCTURE OF CARBONADO OR BLACK DIAMOND

CHAS. R. FETTKE AND FRANK C. STURGES,
Carnegie Institute of Technology.

A typical stone of the variety of diamond known as carbonado, or black diamond, from the Piranhas district in the State of Bahia, Brazil, was selected from a representative lot kindly loaned to the writers by the Pennsylvania Drilling Company for use in connection with this study. In order to examine the structure by reflected light, the specimen was sent to a diamond cutter who ground and polished a small surface on one side.

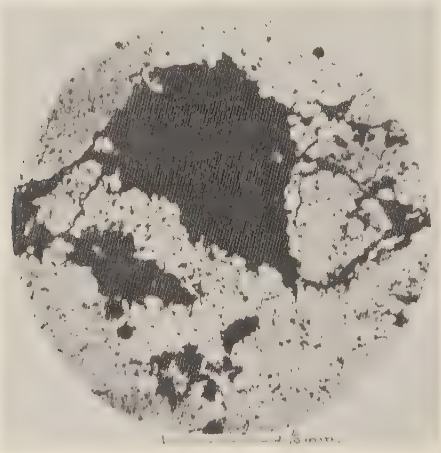

FIG. 1. Polished surface of carbonado.

Under the microscope, using reflected light, the porous structure characteristic of this variety of diamond is well brought out, as is shown in Fig. 1. The pores vary greatly in size, shape, and distribution. This no doubt accounts in large measure for the differences in specific gravity found between different stones as well as differences in behaviour when used in the bit of a diamond core drill.

In order to discover, if possible, further structural features, the polished surface was etched by flashing the oxidizing flame of a blow-pipe over it for approximately ten seconds. The surface then

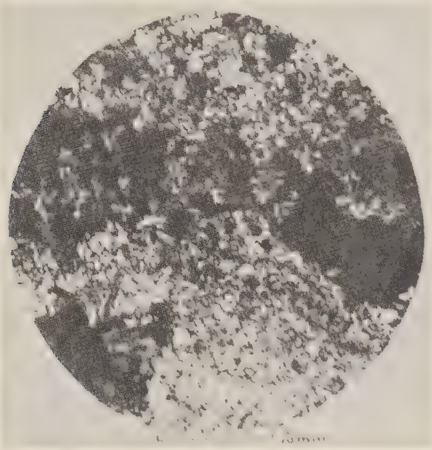

FIG. 2. Etched surface of carbonado.

took on the appearance shown in Fig. 2. Apparently the carbonado is made up of a large number of very small individual interlocking units, for the most part irregular in outline, resulting in a structure resembling somewhat that developed in some varieties of cryptocrystalline quartz. No doubt the toughness exhibited by the carbonado, which makes it so desirable for the bits of the diamond core drills, can be attributed to this characteristic.

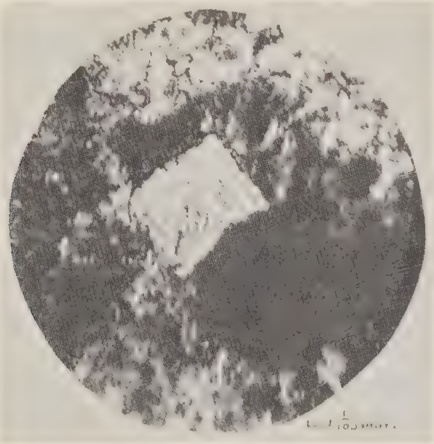

FIG. 3. Minute diamond crystal in cryptocrystalline matrix of carbonado.

Perhaps the most interesting feature brought out by the etching is the presence of actual minute octahedral crystals, ranging in diameter from .063 to .095 millimeters, amongst the individual units that go to make up the carbonado. One of these is shown in Fig. 3.

Walter Gerloch[1] has investigated the diffraction pattern of the carbonado obtained by the powder method of *X*-ray analysis and has compared this with those obtained from the ordinary diamond and graphite. The only difference observed between the pattern obtained from the carbonado and that from an ordinary diamond was an intense darkening of the background of the former. No indication of the presence of crystalline graphite was observed on the carbonado pattern. Gerloch concluded that carbonado consists of a very large number of small interlocking normal diamond grains with perhaps a little intermingled and finely distributed amorphous carbon. The effect produced upon a polished surface of the carbonado by etching with a blow-pipe apparently substantiates these conclusions. It further shows that some of the small individual units have actually assumed the octahedral form which is so characteristic of the diamond proper.

NOTE ON THE ALTERATION OF GALENA TO ANGLESITE, TO CERUSSITE

Carl Swartzlow, *University of Missouri.*

Several specimens of galena, with their surfaces covered with alteration products which show clearly the sequence of its alteration, were found by Dr. W. A. Tarr in the southeast Missouri lead belt. These specimens came from the residual clays over the Bonneterre dolomite and show galena altered to anglesite, and the anglesite in turn altered to cerussite. Some veinlets and incrustations of dolomite are also present.

The galena shows all the characteristics commonly associated with that mineral. On a crystal, about one cubic inch in volume, one face shows a deposit of anglesite about 3 millimeters thick. The anglesite is dark gray in color and is soft and earthy. The earthy anglesite is in layers, eight layers being the greatest number found on any specimen. Some of the layers are lighter colored than the others. The lightest colored layers are on top and the darkest layers are nearest the galena. The colors range from light gray to nearly black.

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[1] Walter Gerloch, Über die Structur des "Schwarzen Diamants." *Zeitschrift für Anorganische und Allgemeine Chemie*, Band **137**, pp. 331–332. 1924.

The cerussite occurs as a thin gray to brownish crust on the anglesite. The brownish color is perhaps due to the oxidation of some of the ferrous iron that was isomorphous with the magnesium in the dolomite, and later stained the cerussite. The cerussite layer is variable in thickness but averages about 0.3 millimeter. On some of the galena crystals the cerussite is found directly on the galena and is not separated from it by anglesite.

The facts that suggest the alteration of anglesite to cerussite are:

1. The contact between the two minerals is gradational. The gradational zone is wavy and irregular, and is parallel to the line of contact.

2. Patches of anglesite are entirely surrounded by cerussite. The largest mass was about 1 cubic millimeter in volume, the others were only a fraction of that amount.

The above observations could also apply with equal weight to the alteration of cerussite to anglesite. However, cerussite is more insoluble and the reaction would tend to go to the formation of the carbonate, instead of the carbonate being altered to the sulfate.

3. Minute cavities in the anglesite are lined with cerussite. Several cavities about .5–1 millimeter in diameter were found to be lined with cerussite. One or two crystals were found about .5 mm. in length but the others were less than .1 mm.

4. Cerussite penetrates the anglesite laminae. In several places the outer two or three laminae have been cut by veinlets of cerussite. Enclosed in the vein material and surrounded by it are small fragments of anglesite.

These alteration products were probably formed by ordinary weathering processes. The galena was first oxidized to anglesite, and the anglesite later converted into cerussite. The probable reactions are expressed by the following formulae:

$$PbS + 2O_2 \rightarrow PbSO_4 \qquad PbSO_4 + H_2CO_3 \rightarrow PbCO_3 + H_2SO_4$$

BOOK REVIEW

THE GENESIS OF THE DIAMOND. Alpheus F. Williams. 2 Vols., XV+636 pages, with 221 plates, many of them in colors. Ernest Benn, Limited, *London*, **1932.**

The author is the son of the late Gardner F. Williams, for many years the general manager of the DeBeers Consolidated Mines, Limited, and known throughout the world for his "The Diamond Mines of South Africa" published in 1902. As the successor of his father in the management of the DeBeers Company, A. F. Williams has had an unusual opportunity to continue the study of the geological occurrences and of the various physical properties of the diamond, especially as it is found in the kimberlite of Africa. The results of these studies and observations are recorded in these two volumes, which may well be considered as supplementing and bringing up-to-date the monumental and classic work of his father.

Volume one includes a brief description of present day diamond mining practice and an exhaustive discussion, covering ten chapters, of the occurrence of kimberlite and of the various characteristics of that important diamond bearing rock. What the author calls the "cognate inclusions" of the diamond are described in great detail in the first chapter of Volume two. The other chapters of the second volume are devoted to a consideration of the properties and interesting features of the diamond itself, and to the occurrences of the gem in the alluvial gravels of the Union of South Africa.

Although there are evidences of considerable repetition and at times one feels that the material is perhaps presented in too much detail, the two volumes must be recognized as very substantial contributions to our knowledge of the diamond. The illustrations and the typography are excellent.

Edward H. Kraus

PROCEEDINGS OF SOCIETIES

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences of Philadelphia, December 1, 1932

A stated meeting was held on the above date with the president, Mr. Trudell, in the chair. Forty-two members and forty-two visitors were present. The following were elected members: Messrs. Charles G. Cadwallader, Arthur Dornblum, William L. Grierson, James W. Knorr, Jr., and Karl Waage.

A symposium on "Cutting and Polishing Stones" was held under the direction of Mr. Stephen Varni. Mr. Varni outlined the types of cutting used in various stones. Mr. H. E. MacNelly gave details on the methods he used in cutting and polishing cabochons. Mr. Arthur Knapp exhibited his remarkably efficient slicing, cutting, and polishing apparatus built from hardware obtained from the 5, 10 and 25 cent stores. Particularly effective was his automatic control, made from parts of a meat-grinder, which permitted accurate facetting of stones. He exhibited a series of cut stones. Mr. Carl Supp, a Brooklyn High School student, exhibited a collection of cabochon stones that he had cut and polished on a set of laps which cost less than $5.00. He described his procedure briefly.

W. H. Flack, *Secretary*

Academy of Natural Sciences of Philadelphia, January 5, 1933

A stated meeting of the society was held on the above date, with President Trudell in the chair. Forty-three members and thirty-six visitors were present.

Dr. Joseph L. Gillson, recently returned from India, addressed the society on (1) The Gem Deposits of Ceylon, and (2) Geological Features of the Ilmenite Deposits of Travancore: illustrated with moving pictures and specimens.

The Ceylon gem deposits are sixty miles southeast of Colombo. All of the stones (sapphires, amethysts, etc.) are found in stream placers. After the gem gravel is washed in nearby streams, the stones are picked by hand. They are then roughly cut by natives on violin-bow powered iron discs, and marketed at native bazaars in Ratnapura.

Dr. Gillson's investigations disproved the assertion that the ilmenite sand deposits along the coast of Travancore were being constantly renewed by currents from off-shore. The deposit consists of a 6000 foot black sand beach averaging 70% ilmenite and 12% garnet. The origin of the deposit was discussed, and details of the seasonal shift of the sands were described. Primitive methods by native workers are used in gathering the ilmenite.

W. H. Flack, *Secretary*

NEW YORK MINERALOGICAL CLUB

Minutes of the Meeting of February 17th, 1932.

A regular meeting of the New York Mineralogical Club was held at The American Museum of Natural History on the evening of February 17th, 1932, with an attendance of 65. President Allen was in the Chair.

A motion was passed to send twenty-five dollars through Prof. E. S. Dana to aid Austrian mineralogists.

Dr. Waldemar T. Schaller of the U. S. Geological Survey was the speaker of the evening, his subject being "Some Fascinations of Mineralogy." Dr. Schaller touched on researches with which he is personally acquainted—minerals of the copper silicate series; polymorphous minerals; color of minerals; and the age relations of minerals. He also discussed the crystal cavities in the trap rock of Paterson, N. J. These are accounted for as due to glauberite crystals formed in Triassic mud in shallow lakes which were covered by molten lava. The sequence was: extrusion of lava, production of glauberite, followed by formation of quartz masses, datolite, zeolites, calcite, and babbingtonite. Following a period of questioning and discussion, a rising vote of thanks was given Dr. Schaller.

Alfred C. Hawkins, *Secretary pro tem.*

Minutes of the Meeting of March 16th, 1932.

A regular meeting of the New York Mineralogical Club was held at The American Museum of Natural History on the evening of March 16th, 1932, with an attendance of 52. President Allen occupied the Chair.

Mr. Fred W. Schmeltz of New York City was elected to membership.

Mr. Morton reported for the Committee on the Mineralogy Manual, appointed at the January meeting, that Mr. Peter Zodac was working on a similar project, and he would confer with the latter.

The following were named to serve on the Nominating Committee for the annual election of officers in April: Dr. Whitlock, Professor Findlay, Professor Butler, Professor Kerr, Mr. Manchester, and Mr. C. Fluhr.

Dr. J. F. Schairer of the Geophysical Laboratory, Carnegie Institution, Washington, D.C., addressed the Club on "The Synthesis of Rock Minerals." He briefly traced the history of experimental mineralogy and described methods of synthesizing minerals. He showed views of the laboratories and described a number of projects recently carried out. The mineralogical and petrological significance of an incongruent melting point was stressed. Details of crystallization of certain mixtures were presented to indicate how equilibrium diagrams explain mineral associations in rocks and throw much light on the problem of magmatic differentiation. Slides were shown to illustrate the subject.

After the usual questioning and discussion, the Club gave a rising vote of thanks to Dr. Schairer for his excellent lecture.

The Nominating Committee presented the following names to serve as officers for the year 1932–33:

President: Dr. Alfred C. Hawkins
Vice President: Mr. George E. Ashby
2nd Vice Pres. Dr. Horace R. Blank
Secretary: Dr. Daniel T. O'Connell
Treasurer: Mr. Gilman S. Stanton

Dr. Myron H. Clarke distributed a number of excellent specimens of concretions from a locality near Basking Ridge, N. J.

Daniel T. O'Connell, *Secretary*

NEW YORK MINERALOGICAL CLUB

Minutes of the Meeting of April 20th, 1932.

A regular meeting of the New York Mineralogical Club was held at The American Museum of Natural History on the evening of April 20th, 1932, with an attendance of 64. President Allen was in the Chair.

Miss Gertrude Coller, and Miss Helen Forsberg of the Bronx; Mr. Scott Ellis of Short Hills, N. J.; and Mr. Arthur E. Woods of Orange, N. J., were elected to membership.

The following officers for the Year 1932–33 were elected unanimously:

President: Alfred C. Hawkins
1st Vice Pres.: George E. Ashby
2nd Vice Pres.: Horace R. Blank
Secretary: Daniel T. O'Connell
Treasurer: Gilman S. Stanton

President Hawkins appointed the following standing committees for the ensuing year:

Membership Committee: Messrs. Ashby and Grenzig and Miss Catherine Schroder.

Excursion Committee: Messrs. Manchester and Hoadley

Treasurer Stanton's report was approved as read. President Hawkins appointed Mr. Radu and Dr. Blank as auditors. The balance in the Club treasury on April 20th, 1932 was $538.88. Attention was called to the fact that Mr. Stanton had just been elected Treasurer of the Club for the thirtieth time.

Dr. C. A. Hartnagel, Assistant State Geologist, spoke on "The Minerals and

Mineral Industries of New York State." The lecture was illustrated by lantern slides. A rising vote of thanks was given by the Club for this very interesting lecture.

Daniel T. O'Connell, *Secretary*

Minutes of the Meeting of May 18th, 1932

A regular meeting of the New York Mineralogical Club was held at The American Museum of Natural History on the evening of May 18th, 1932, with an attendance of 68.

The resignation of Dr. Albert D. Bardes was accepted with regret.

Communications were read by the Secretary from: *Newark Mineralogical Society* expressing their intentions of joining with our Club on its Memorial Day Excursion. *Samuel G. Gordon of the Philadelphia Academy of Sciences,* requesting a list of members of the Club having mineral collections for the catalogue of the Mineralogical Society of America.

Mr. Manchester of the Excursion Committee reported that all arrangements for the Club's excursion to the Bedford Quarries on Decoration Day, May 30th, had been made and stated that it would be a pleasure to have the Newark Mineralogical Society with us.

Dr. Horace R. Blank, Assistant Geologist of the Board of Water Supply of the City of New York, gave the address of the evening on "The Minerals of New York City's New Water Tunnel." He exhibited a large collection of the minerals collected under his supervision from the shafts and tunnel of City Water Tunnel No. 2 which extends from Hill View Reservoir to Erie Basin, near Brooklyn; comprising specimens from all the rock formations of New York City.

In the discussion which followed, Dr. Blank and Mr. Fluhr were publicly commended by Mr. Merriman, Chief Engineer of the Board of Water Supply, for the most detailed geological record ever made of such a project.

Daniel T. O'Connell, *Secretary*

NEW MINERAL NAMES

Vandenbrandeite

Alfred Schoep: La vandenbrandeite, un nouveau minéral uranifére (Vandenbrandite, a new uranium mineral). *Ann. Mus. Congo Belge.* A. *Min. Géol. Paléon., Ser.* I, *Minéral.* 1, No. 3, 25–31, **1932.**

Name: In honor of P. Van den Brande, who discovered the mineral deposit.

Chemical Properties: A hydrous uranate of copper: 2 CuO. 2 UO_3. 5 H_2O. Analysis (mean): $UO_3$65.45, CuO 15.78, H_2O 9.25, PbO 4.69, SiO_2 1.66, Fe_2O_3 1.55, P_2O_5 0.21. Total 98.59. Difficultly soluble in cold acids but easily soluble in hot acid with liberation of a gas. Ammonia gives a blue solution and a bright yellow precipitate. Fuses near 1000° to a black mass, yielding a crystalline bead upon cooling.

Crystallographic Properties: Triclinic. Forms, (100), (110), (001), $(1\bar{1}0)$. Cleavage (001) perfect, another cleavage in the zone (100), (110).

Physical and Optical Properties: Color dark green, sometimes almost black; streak green. Hd. 4. Sp. Gr. 4.96.

The cleavage fragments (001) are dark green in color and contain numerous inclusions, not pleochroic and are almost perpendicular to an optic axis. Dispersion strong. On the cleavage (100):(110), the mineral shows interference colors of gray, dirty yellow, dark violet or lavender blue, depending upon its position but not its thickness. Extinction 35° with the common cleavage edge. Pleochroism green to colorless. N_g (of cleavage) 1.80, N_p (of cleavage) 1.77. $\beta = 1.78 \pm .02$.

Occurrence: Found in a new uranium deposit at Kalongwe, 2 kms. east of the point Karungwe, Belgian Congo, associated with pitchblende, chalcopyrite, chalcocite, kasolite, skladowskite and malachite. It is an alteration product of pitchblende and chalcopyrite.

W. F. Foshag

Letovicite

J. Sekanina: Letovicit, ein neues Mineral und seine Begleiter (Letovicite, a new mineral and its associates). *Zeit Kryst.*, **83**, 117–122, 1932.

Name: From the locality, Letovice, Moravia, Czecho-slovakia.

Chemical Properties: An acid sulfate of ammonia, $H(NH_4)_3(SO_4)_2$. No quantitative analysis given. Easily soluble in water. Easily and completely volatile.

Crystallographical Properties: Corroded crystals tabular to (001).

Physical and Optical Properties: Colorless to cloudy. Fracture uneven. Cleavaage parallel to (001), poor. Sp. Gr. $= 1.81$. Biaxial negative. Plane of the optic axes is perpendicular to (010). $\alpha = 1.501$. $\gamma = 1.526$. Twinning lamellae observed.

Occurrences: Found with α-sulfur and paramorphs of α after β-sulfur on coal and carbonaceous shale at Písěcná, near Letovice, and presumably formed by the spontaneous combustion of coal.

W. F. F.

Duparcite

S. E. Nicolet: Un Minéral Nouveau, la Duparcite. *Schw. Mineral. Petr. Mitt.*, **12**, 543–545, 1932. (Abs.) E. Brandenberger: Röntgenographische Untersuchung des Duparcite. *Ibid.*, pp. 545–546.

Name: in honor of Prof. Duparc.

Chemical Properties: A silicate of aluminum and calcium. Analysis: SiO_2 36.56, Al_2O_3 16.43, Fe_2O_3 1.60, FeO 4.37, MgO 3.01, CaO 32.84, K_2O 0.63, Na_2O 1.55, ign. loss 2.73. Sum 99.72.

Crystallographical Properties: Tetragonal. Habit prismatic, greatly elongated. Faces (110), (100), more rarely (001) and (111).

Physical and Optical Properties: Color greenish gray. Pleochroism weak. N_g = colorless. N_p = very pale yellowish. Hd. $= 7.5$, Sp. Gr. $= 3.42$. Cleavages, (100), (010) and (001). Optically negative. $N_g = 1.706$, $N_p = 1.698$. $c = 11.82$ Å

Occurrence: Found in the aphanites of Azegour, Morocco.

Remarks: Closely related to vesuvianite but differs from that mineral in several minor respects.

W. F. F.

Tuhualite

P. Marshall: Notes on some Volcanic Rocks of the North Island of New Zealand. *N. Z. Jour. Sci. Tech.*, **13**, 202, 1932.

Name: From the locality, Mayor Island (Tuhua Island of the Natives), New Zealand.

Optical Properties: Color violet, strongly pleochroic; colorless to purplish violet, to deep violet.

Occurrence: Found sparingly in comendite with aegerite, cossyrite and arfvedsonite.

Discussion: This amphibole differs from others in its strong violet pleochroism.

W. F. F.